BLUE MOLD
(DOWNY MILDEW)
Disease of Tobacco

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BLUE MOLD is a destructive tobacco seedbed disease throughout the area from Pennsylvania to Florida. Losses depend on weather conditions. Disastrous epidemics occurred in 1932 and 1937.

The disease is caused by a fungus (*Peronospora tabacina*), which attacks and destroys the leaves. Usually diseased plants throw out new leaves and recover, but under some conditions large numbers may be killed, particularly if the plants are infected when they are very young.

The disease is favored by cloudy weather and temperatures between 50° and 70° F. Destructive epidemics have occurred in years when warm winters were followed by very early disease appearance.

Results from studies on control measures are as follows:

(1) Cultural practices: Growers have materially reduced blue mold damage by enlarging their seedbed areas and delaying transplanting until recovery has occurred. However, if the disease attack is severe these measures may not be adequate.

(2) Heat treatment: Raising the night temperature to between 70° and 90° F. will control the disease effectively, but at present this method is not considered practical.

(3) Gas treatment: Benzol or paradichlorbenzene is vaporized in the seedbed, and the fumes are held in by means of muslin cloth or other tight covers. This method is effective but costly.

(4) Spray treatment: The spray used is a mixture of cuprous oxide and cottonseed oil, and, on an average, 8 to 12 applications are required. This method is not as completely effective as the gas treatment, but it is inexpensive.

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BLUE MOLD (DOWNY MILDEW) DISEASE OF TOBACCO [1]

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CONTENTS

INTRODUCTION

BLUE MOLD is probably a native North American disease which occurs generally on wild tobaccos in the West. Apparently because commercial tobacco culture in the United States has been centered in the East, where no native tobaccos occur, our growers were not troubled by this disease until it appeared in Florida in 1921. Surprisingly, it disappeared, and was not seen again until 1931. The disease is now well established and has occurred since 1931 throughout the area from Florida to Pennsylvania. Each year the mold has first appeared between December and March in or near Berrien County, Ga.; from there it apparently spreads southward into Florida and then develops to the north as the season advances. In 1937 the disease also occurred in Tennessee, Kentucky, Indiana, Ohio, and Connecticut, but so far it has not been a very serious problem in these States. It is a seedbed disease, and the occasional early season field infections have been of no consequence. Work on control measures was initiated in 1932 and has been continued without interruption. This work is still in progress, and material improvements in control methods may be expected in the future. However, 1937 provided a severe test for the control measures that had been developed, and the results obtained show conclusively that this disease can be controlled, even under the destructive conditions that prevailed in Georgia in 1937. Furthermore, this can be done at very moderate cost. The information here presented applies particularly to the flue-cured tobacco region.

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[1] Based on cooperative investigations carried on by the Bureau of Plant Industry, the Georgia Coastal Plain Experiment Station and State College of Agriculture, the South Carolina Experiment Station, the North Carolina Department of Agriculture and State Agricultural Experiment Station, and the Maryland Agricultural Experiment Station.

THE DISEASE

SYMPTOMS

The usual first indication of blue mold in a bed is the appearance of one or more circular patches of yellowed leaves. Careful examination in the center of such a patch will show a few leaves with the characteristic cottony fungus growth on the lower surface (fig. 1). This growth is either white or pale violet in color. There are two common troubles with which blue mold is confused. Yellowed patches of plants sometimes appear in a bed because of malnutrition, and frost injury may yellow leaf tips. In neither case, however, is any cottony mold growth to be found.

After the infection has appeared, it usually progresses slowly for several weeks. Then a general outbreak occurs, and the entire bed becomes diseased almost overnight. The severity of this attack will depend on the weather and the age of the plants. Young plants may be killed outright; older ones may be reduced to stem and bud. During this period, also, the roots of affected plants turn brown. The plants in the bed look very sick at this time, but in a few days some of them may begin to recover. The rate of recovery will depend on the severity of the attack and the weather. If many leaves are only partly killed and the weather turns warm, recovery will be very rapid. On the other hand, with continued cool weather, recovery may be very slow. Ultimately, however, practically all the surviving plants recover completely and make a normal growth when transplanted to the field. Also, no matter how mild or severe the attack, once recovery has occurred, the plants are so resistant that serious damage from a second mold attack before the plants are ready to set need not be feared (fig. 2).

LIFE HISTORY

Blue mold is caused by a fungus (*Peronospora tabacina* Adam). The cottony fungus growth seen on the lower leaf surfaces is made up of sporophores and spores (fig. 3), which correspond to the trunk, branches, and fruit of a tree. The mycelium, from which the sporophores arise, grows through the tissues of the leaf and secures its food from these. This fungus can only survive as long as the leaf remains alive; as soon as the leaf dies, new sporophores and spores stop appearing on the surface. Leaves may be seen with a dead brown area surrounded by a diseased yellow area, which is covered with fresh sporulation.

The disease is spread by means of spores which are so light as to be readily carried by air currents. At times the spores are carried long distances, 50 to 75 miles or more; hence no seedbed in an affected area is likely to escape the disease, although some will be infected sooner than others. Spores that chance to fall on tobacco leaves will germinate, if moisture is present, and grow into the leaf in a few hours. Once inside, the mycelium continues to grow, the infected area gradually yellows, and in about 7 days the cottony growth develops on the under-leaf surface, indicating that a new crop of spores has been matured. They form in the early morning, and most of them are dead by 9 a. m. A few, however, live longer; under favorable conditions some have remained alive 2 weeks.

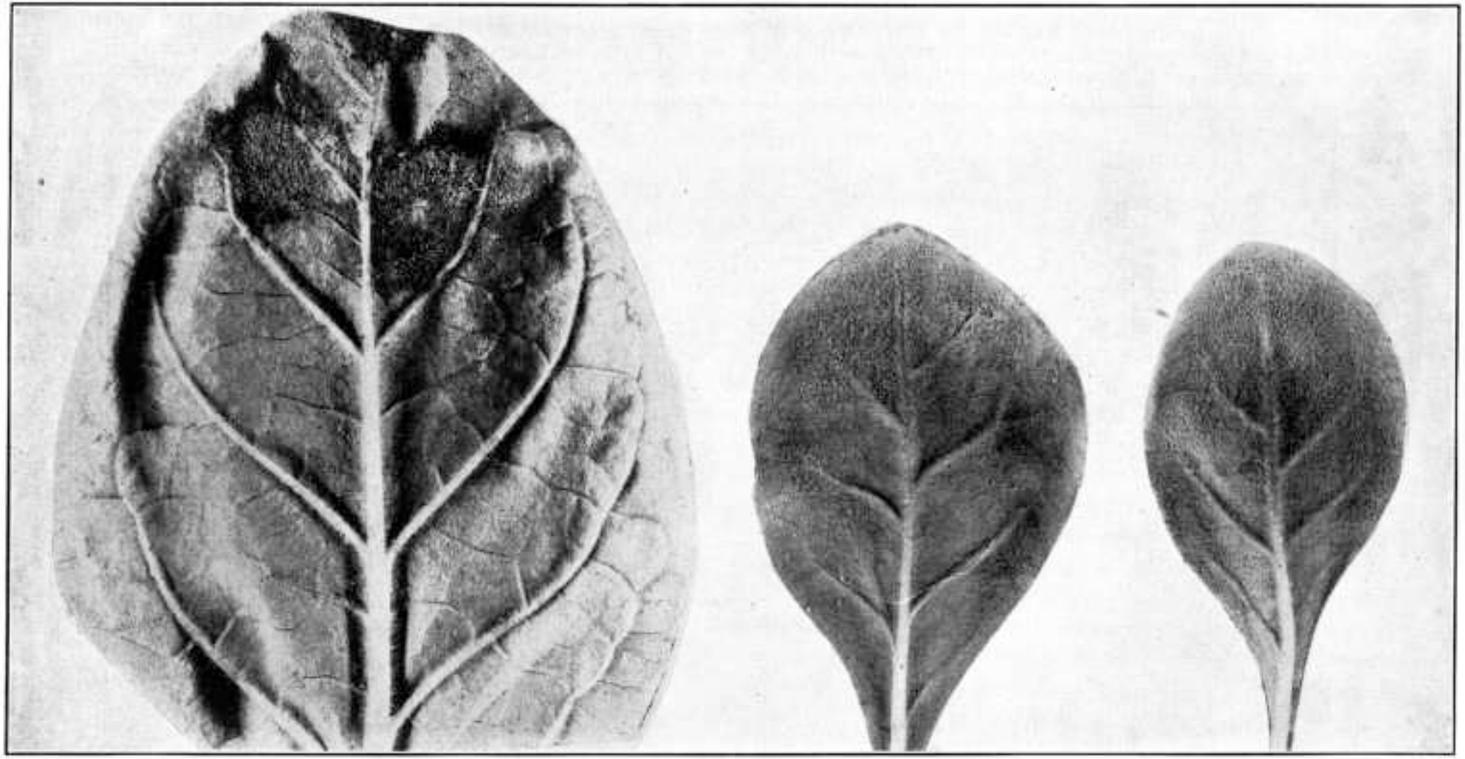

FIGURE 1.—Blue mold symptoms: The cottony growth of fungus on the lower leaf surface. Note that the small leaves from young plants may have the lower surface practically covered, while with large leaves the lesions are more definite and limited. This growth is usually white but may be pale violet, and its presence distinguishes the disease from leaf yellowing caused by malnutrition or frost.

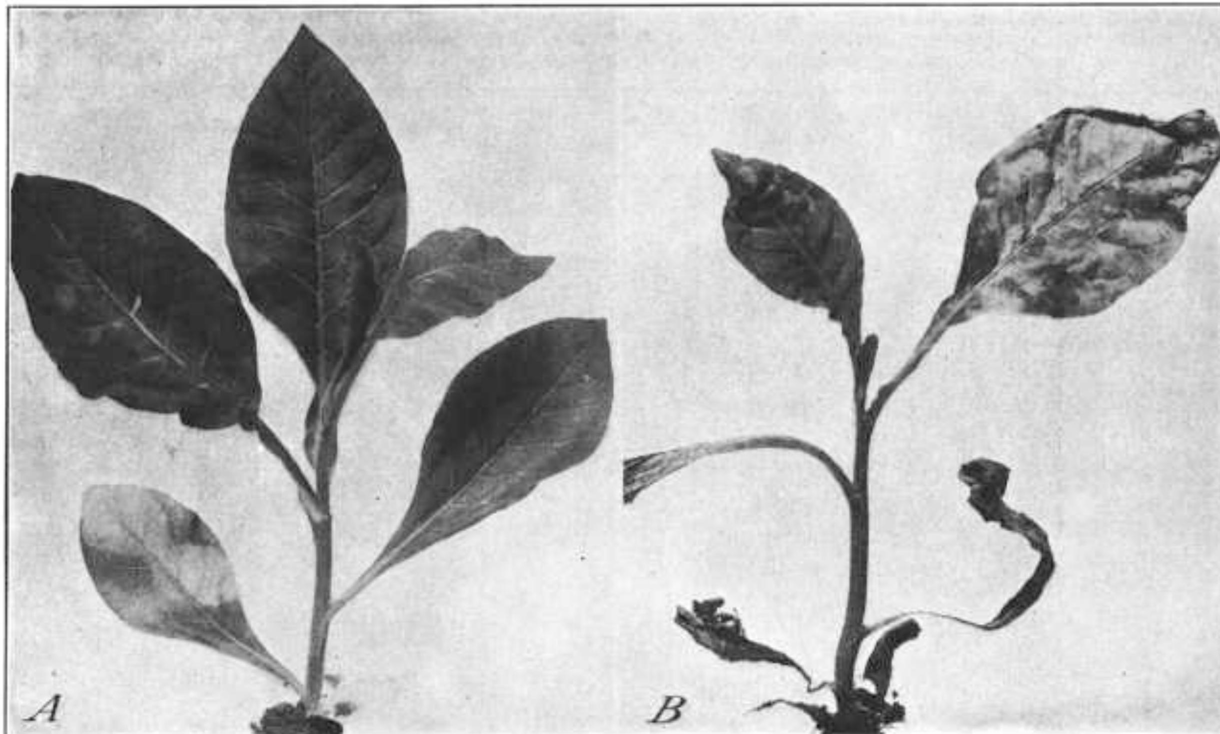

FIGURE 2.—Comparative susceptibility to blue mold of recovered and freshly infected plants. Both plants were exposed to the same general severe blue mold attack. Plant *A* came from a part of the seedbed that had been affected 2 weeks earlier and had recovered, while plant *B* was attacked for the first time. Plant *A* was reinfected, as is indicated by the light-colored areas on several leaves, but was practically uninjured, whereas the larger leaves of plant *B* were killed.

The fungus occasionally produces another kind of spore, the resting or oospore. This spore is long-lived and enables the infection to persist in the soil of old seedbeds. It is also possible that in some localities the infection may remain alive in plant tissues and, if these survive the winter, be carried over into the next season.

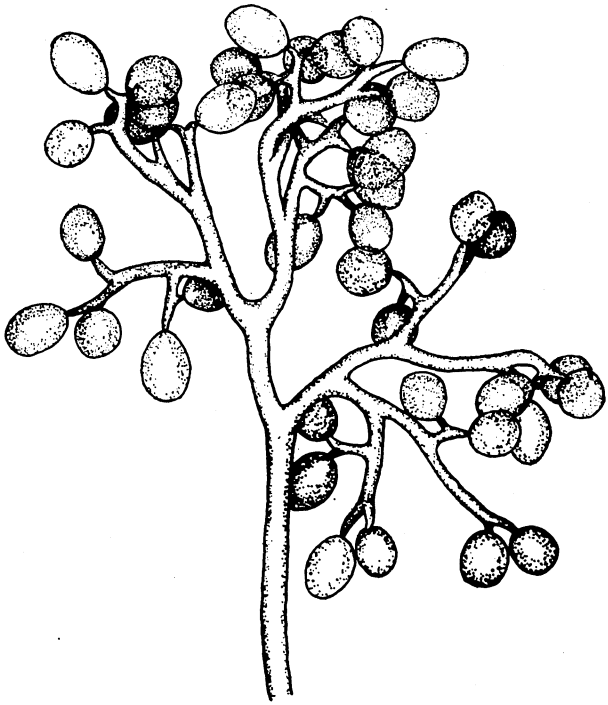

FIGURE 3.—A sporophore bearing spores. The oval spores are very light and are easily carried through the air from leaf to leaf (× about 300). The cottony growth seen on the lower leaf surfaces is made up of a mass of these sporophores.

RELATION OF WEATHER CONDITIONS

Blue mold is particularly responsive to temperature (fig. 4) and moisture conditions. Since 1931 most beds throughout the flue-cured area have been infected each year, but in only 2 years has the disease been generally destructive. Each of these years a warm winter with frequent cloudy days was followed by an unusually early appearance of the disease in the plant beds. Consequently, in the future, growers should be warned by this combination of events. During the early spring, with minimum night temperatures between 40° and 50° F., the disease does not develop rapidly. Infected leaves may remain alive some days, producing new spore crops each night, and infection may remain apparently confined to certain limited areas of the plant bed.

The epidemic outbreak, when the entire bed is affected, comes with warmer nights—usually with a minimum temperature of 50° or more, accompanied by fogs or light rains. Heavy rains, for some reason,

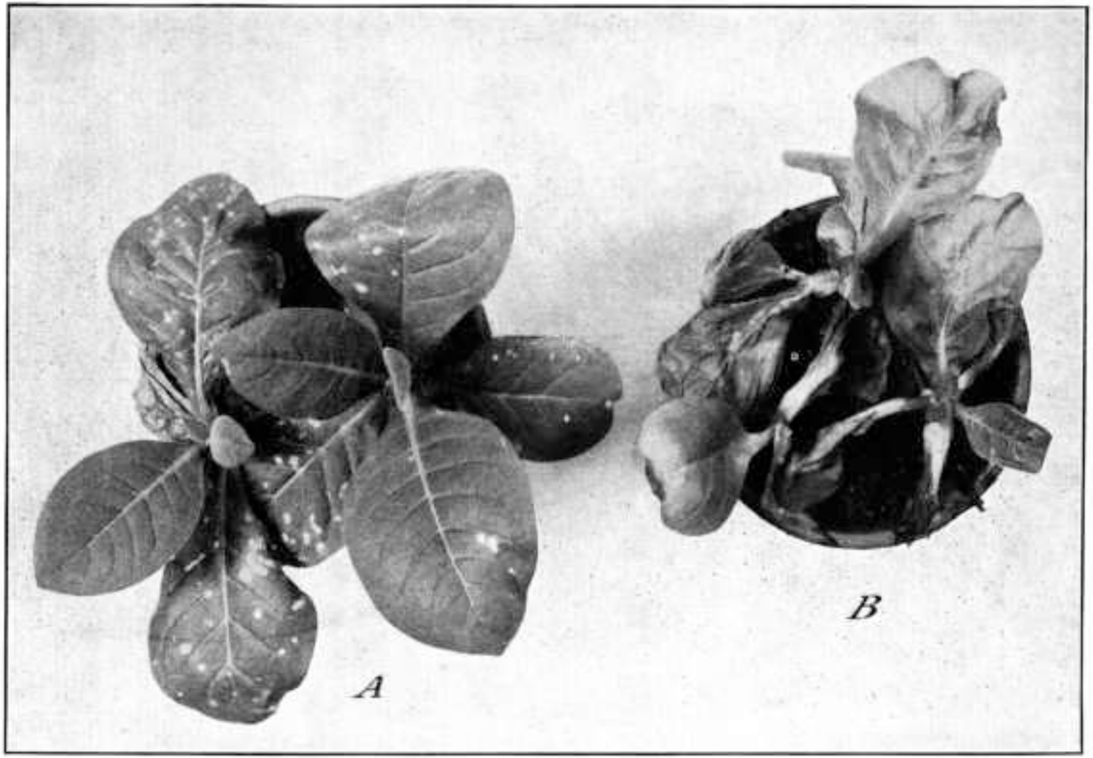

FIGURE 4.—Blue mold response to temperature conditions. The plants shown were uniformly infected. Pot *A* was then moved into a warm temperature (70° to 110° F.), and the fungus produced the small white lesions and then died out completely. Pot *B* was moved to a cool temperature (60° to 80° F.), and the fungus continued active.

tend to check mold development. However, if favorable temperatures prevail early and infection becomes well distributed, even though cool weather follows, the disease may continue to be very destructive. As the minimum night temperature rises to between 65° and 70°, the disease disappears. At this temperature, and in fact up to temperatures as high as 75°, the mycelium is very active, but usually the leaf tissues die very quickly and produce few, if any, spores. This automatically brings the activity of the disease to an end.

HOST PLANTS

Blue mold is primarily a disease of tobacco. However, peppers are occasionally affected severely, and slight infections have been observed on tomato and eggplant. There is a similar-appearing but entirely distinct fungus that attacks collards and cabbage.

LOSSES

The disease affects the crop in several ways. (1) The disease may kill plants outright. In most beds there are enough plants so that even as much as a 50-percent loss would still leave a fair stand. In 1932 and again in 1937, however, the percentage kill in some localities was so high that an acute shortage of plants resulted. (2) There is the problem of delay in transplanting. Whenever the disease occurs there is some delay. If the attack is light and the recovery prompt, the delay may be less than a week; if the attack is more severe, there may be a delay of 4 or 5 weeks. Most growers set tobacco "on a season," and if one or more favorable planting times are lost because of mold, this delay may be serious. In addition, if planting is much delayed, the crop may be late, and such crops usually are lacking in yield and quality. (3) There may be a poor stand as a result of transplanting diseased plants. The growers are well aware that plants must recover from the disease before they can be safely set. However, the situation frequently arises that weather and land conditions are favorable for transplanting, but the plants show some disease. Then it is always a question whether to plant and risk a poor stand or not to plant and miss a good season. (4) When considering losses, it should be remembered that because of the mold thousands of growers are now going to the labor and expense of growing 100 square yards of seedbed per field acre, whereas before the mold became prevalent, half this area was considered adequate. This added expense alone is a large item.

CONTROL MEASURES

CULTURAL PRACTICES

As recommendations for control by cultural practices have been put forward many times, they will be stated only briefly here.

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Avoiding early infection.—In certain parts of the South, plants may live over in old beds, develop mold very early, and serve as a source of infection for nearby new beds. Also, volunteer seedlings from parent hold-over plants left in old beds may become infected and enable the fungus to get an early start. To prevent this, hold-over plants should be destroyed before they produce seed. It has already been pointed out (p. 5) that the infection may persist in the soil of old seedbeds; if such soil is used a second year and is sown early, the plants may be exposed to an early attack. Lastly, if both early and late beds are sown, it is advisable to separate them, because the early beds develop mold first and may then serve as a source from which abundant infection is spread to nearby late beds.

Growing plants ahead of the disease.—In 1937 many growers sowed their tobacco beds earlier than usual and, to further hasten growth, used frequent applications of nitrate. However, in Georgia, despite the fact that the plants were much ahead because of early sowing and a warm winter, blue mold was unusually severe and destroyed 80 percent of the plant crop. In addition, many early plants were injured by frost. On the other hand, early sowing worked out very well in some localities in 1938. First, the plants were too far ahead, and then a mild attack of blue mold delayed them without causing any serious damage. The uncertainty of results would suggest that too much dependence should not be placed on early sowing as a means of evading the disease and that a better plan would be to follow the best agronomic recommendations both with respect to fertilization and time of sowing and then adopt other more reliable measures to cope with blue mold.

Early sowing presents the additional problem that in some years, in the absence of blue mold attack, the plants may reach transplanting size too soon.

Sunny bed locations.—It is unquestionably true that mold is more severe in shady beds and in the shady parts of a bed; hence, excessive shade should be avoided. However, sunny locations may also be dry locations; in South Carolina, in 1938, such beds gave poor stands of plants.

Thin or thick stands.—The value of thin stands has been frequently mentioned, but close study of many beds has failed to show any gain in blue mold control in thin stands. Some thin stands were reduced to a few scattering plants in 1937, while in thicker stands enough plants survived to give a fair yield.

Removal of covers.—Covers are generally removed as soon as the weather permits; earlier removal could hardly be recommended, because if covers are removed too early, the plant growth will be stunted. After the disease has developed, removing the covers has little effect on the mold.

Increased seedbed areas.—Reference has already been made to the fact that throughout the flue-cured area growers are planting vastly larger seedbeds. Many expect to get only one or two good pullings, whereas formerly they obtained three or four. Increased seedbed area is unquestionably the most effective cultural method to insure an adequate supply of plants.

Hastening recovery with applications of nitrate.—After plants have been defoliated by the disease, it is essential that they grow

new leaves. Beds may be short of nitrogen at this season and, when this is the case, one or more light applications will aid recovery. Many growers have started making heavy applications of nitrate as soon as the disease appeared; this has frequently resulted in severe plant injury.

Allowing plants to recover before transplanting.—Experiments and the experience of growers combine to show that once the mold appears, it is not advisable to attempt to hurry plants to the field. Rather, they should be allowed to remain in the bed until the disease attack has passed and recovery is apparent. As soon as new leaves and roots are produced, the plants can be set out safely.

Growers who prefer to depend on cultural practices to combat blue mold should continue to plant very large seedbeds and, after the disease appears, should delay transplanting until the surviving plants have recovered. In regard to bed location, fertilization, rate of sowing, and the handling of covers, while some thought should be given to blue mold, the primary consideration should be the best agronomic recommendations for the area.

HEAT TREATMENT

Blue mold attacks are limited to the spring because this disease is unable to develop in hot weather. This fact suggested the value of heating the seedbeds. Extensive experimentation has shown that if night temperatures in the usual type of spring beds are raised to between 70° and 90° F., good control of the disease is obtained. Many forms of heat have been used. Electric heating cables laid on the soil surface proved very convenient and effective, but electricity is an expensive source of heat. Kerosene burners, such as are now used to some extent in curing, have probably been the most satisfactory source of heat. The heat and fumes from such burners tend to reduce humidity and harden plants slightly, but this appears to be an advantage. To use heat treatment, it is necessary to construct tight beds and to provide covers. Glass sash has been the most satisfactory cover. Glass substitutes and heavy cloth have been used but were not so effective. Heat treatment does not appear practicable, however, because it involves too much labor and expense. The cost of heat protection against blue mold is estimated to be at least $60 per 100 square yards of bed.

GAS TREATMENT

Blue mold can be entirely eliminated by gas treatment with benzol or paradichlorbenzene, but to obtain the best results beds must be properly constructed. In preparing to use the vapor or gas method of treatment, it is essential that the beds have tight side walls about 10 inches high. Then, an overhead framing of light board strips and wire is required. This must be strong enough to hold the muslin cover when it is wet and heavy and must be so constructed that the cloth at the highest point in the center of the bed will be 18 to 24 inches above the ground. These beds may be from 9 to 12 feet wide (fig. 5). However, it is much easier to handle the muslin covers if the beds are constructed only 6 feet wide and without the center ridge pole. Such narrow beds if run east and west usually

have the south and north side walls about 10 and 16 inches high, respectively. The cloth must be sufficiently tight to hold in the vapor and yet not so tight as to shed all rain. Extensive tests have shown that unbleached-muslin sheetings with a thread count greater than 65 become practically impervious to rain when they are wet, and that with thread counts much below 55 the vapor-retaining capacity is greatly reduced. Therefore, muslin sheeting with 55 to 65 threads to the inch, weighing at rate of 3.5 to 4 square yards per pound, is recommended.

The muslin cover must make a tight union with the side walls of the bed. A satisfactory procedure has been to fasten the cloth firmly along one side of the bed and weight the free side with strips of board. The board stripping not only holds the free side down firmly at night but is an aid in rolling the cover up in the morning. Various devices can be used to fasten the free side of the cover down even

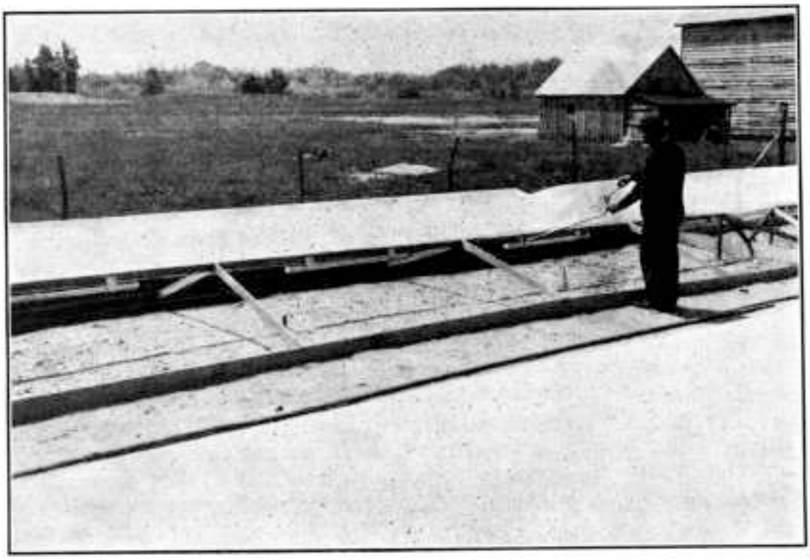

FIGURE 5.—Gas treatment for blue mold control. These beds, 9 feet wide and 68 feet long, were provided with tight sides and an overhead frame to support the cloth sheets. The long, narrow evaporating pans were hung from the ridge pole and provided an evaporating surface of one-hundredth the bed area. The benzol was poured in with the aid of a funnel and tube.

more firmly. Beds that are to receive the gas treatment should not be over 12 feet wide because with increasing width the cloth covers become more difficult to handle; and also, as will be noted later, the problem of distributing benzol or paradichlorbenzene is most difficult with wide beds.

In using either of the gas treatments, but most particularly in the case of benzol, it is desirable to put in the material and close up the beds late in the afternoon. The reason for this is that the muslin covers do not retain the vapors very effectively until after they are wet with dew; hence, during the interval between the time the bed is closed and the formation of the dew, there is a heavy loss of gas through the cover. In cases where mold is very active and

maximum protection is needed at once it may be advisable to sprinkle the covers with water early in the evening, to facilitate maximum retention of vapors, and to continue this sprinkling each evening until the mold is under control. The great advantage of this method is that the vapor treatments do not need to be started until after blue mold has appeared in the bed. The benzol and paradichlorbenzene vapors will not only prevent further development of the disease but will actually check the development of the fungus in leaves already infected. However, the grower should keep his beds under close observation, because, if he delays too long, the disease may cause serious damage before he is aware of the danger. Thus, while in some experiments it has been possible to obtain satisfactory control with only 2 weeks of gas treatment, it is not believed that the grower should plan on less than 3 weeks' treatment, beginning with the appearance of mold infection in his beds. In some localities and during certain seasons even longer periods of treatment may be required. Growers expecting to use gas treatment should begin preparation at the time the beds are seeded and should have all arrangements completed well in advance of blue mold appearance. It is not advisable to stop gas treatments early, because if weather conditions continue favorable for disease development, mold may appear in gassed beds about 1 week after treatments are discontinued.

The cost of gas treatment is difficult to estimate accurately, because as yet this method has not been used commercially in this country. The cost of benzol or paradichlorbenzene will probably range from $5 to $7 per 100 square yards of bed, whereas the cost of cloth, construction materials, and labor will vary with local conditions. A disadvantage that has been encountered in the use of the gas treatment has been the tendency of the plants to become tender, because the beds are covered at night with heavy muslin during a period when normally they would be left uncovered to harden the plants. Also, it should be mentioned that at two experimental locations toxic soil conditions have been observed for some months after treatment. So far these effects have not persisted over winter.

Benzol vapor treatments.—Extensive tests have shown that 1 fluid ounce of benzol per square yard per night is an effective dosage, and an evaporating surface of one-hundredth of the bed area is satisfactory. About 32 inexpensive pie tins of average size are required per 100 square yards of bed. Fewer, larger pans are not so satisfactory, as it has been found that if the pans are more than 6 to 8 feet apart, with the usual muslin covering, the plants farthest away may not be adequately protected. It is not essential, however, to use a fixed evaporating rate of one-hundredth of the bed area. The important thing is to have the evaporators well distributed and to vaporize the benzol during a considerable part of the night. Various types of evaporators have been used successfully. Wick evaporators and tin cans with cloth wicks have been used satisfactorily; troughs filled with sawdust have also proved satisfactory.

Paradichlorbenzene vapor treatment.—This method has been tested only 1 year, and its possibilities have not yet been completely explored. The ordinary coarse, granular paradichlorbenzene was used at the rate of 1 ounce to 4 square yards of bed. The crystals were merely scattered on boards and vaporized slowly during the

night. A convenient arrangement is to nail narrow board shelves inside and near the top of the side wall boards, which should be at least 10 inches high, so that the paradichlorbenzene is above the plants. Beds up to 10 feet wide have been protected by paradichlorbenzene scattered on 2½-inch board shelves on each side of the bed. If the beds are wider than this, one or more lines of evaporating

FIGURE 6.—A sprayed bed on a farm near Tifton, Ga. This photograph was taken March 18, 1937, just prior to the first pulling. A total of 7.3 acres of tobacco was set per 100 square yards of bed.

boards must be laid through the center. Some promising results have been secured with light weight cotton covers, but sufficient data has not yet been obtained to make possible definite recommendations. As with benzol, tight muslin covers hold in the paradichlorbenzene vapor most effectively.

SPRAYING

It is very important that growers understand clearly what to expect from the spray treatment. This treatment is not intended to eliminate blue mold. It may reduce the amount of mold to a trace, or there may be a general development of the disease over a 3- to 4-day period. But, while the spray treatment does not eliminate mold, it does reduce disease development to such an extent that little or no actual damage is caused. It prevents appreciable loss of plants; it prevents serious transplanting delays; and it prevents poor field stands insofar, of course, as these may be caused by blue mold. Obviously, if the disease causes no measurable damage, as is frequently the case, there will be no gain from spraying; on the other hand, the results from a large number of tests show that the more severe the blue mold attack the greater has been the gain from spraying. The spray treatment may be regarded as an insurance that makes it possible for a grower to sow only his usual bed area at the usual time without fear that he may be short of plants or delayed in planting because of blue mold. It requires less expense and labor to spray the regular bed area than to double the bed area and not spray, as many are doing at present (figs. 6 and 7).

Spray equipment.—While it is true that good spraying can be done with practically any equipment, provided it is used properly, experience has shown that certain types of sprayers (fig. 8) are particularly adapted to work in tobacco beds. There are large-sized bucket pumps with horizontal handles which easily maintain pressures of 100 to 125 pounds. Such outfits are recommended for growers having up to 400 square yards of bed area. For larger bed areas, barrel outfits of various sorts are most satisfactory. Growers who use bucket pumps or outfits that hold but a small amount of spray will find it more convenient to mix a 25- or 50-gallon lot of spray in a barrel and dip it out as needed, rather than to mix four or five small batches. The spray solution, of course, should be stirred well before it is dipped. The spraying hose is an important item, and it should be long enough to reach different parts of the bed easily. A bucket outfit should be provided with at least 25 feet of hose and the barrel outfit with at least 50 feet. Fabric-reinforced, ⅜-inch hose is satisfactory, whereas molded rubber hose without fabric reinforcing is not recommended. If the spray outfit is to be used to emulsify the oil, as described later (p. 17), a separate short length of hose with pump and nozzle connections should be provided. A spray rod is necessary, but the length may range from 6 to 10 feet, depending on preference. The rod should be made of ¼-inch pipe with a cut-off at the base. One or two nozzles are mounted at the end of the rod at either a 45° or full right angle. If two nozzles are used, they must be adjusted by actual trial so as to deliver a uniformly distributed spray. The rate of spray discharge depends on pressure and nozzle aperture. It is desirable to use a small nozzle

opening early in the season to throw a finely divided spray at a slow rate. Later, as increased amounts of spray are required, the opening in the nozzle disk can be made larger. Extra disks with larger or smaller openings can be purchased for a few cents.

FIGURE 7.—Unsprayed check bed on the farm shown in figure 6. Blue mold killed 84 percent of the plants, and the total set was 1.7 acres per 100 square yards of bed.

Spray materials.—The recommended spray is a mixture of copper oxide and emulsified cottonseed oil. Generally finely-ground red copper oxide, 85 to 90 percent copper, is used. In addition to this, however, mention should be made of several other copper oxides that give satisfactory results. (1) "Cuprocide 54" is a red copper oxide to which materials have been added which facilitate mixing with water. Cuprocide 54 remains in suspension longer than regular red cuprous oxide. Because of the materials added, it is necessary to increase the amount used by 50 percent. Thus, for each pound of regular copper oxide, 1½ pounds of Cuprocide 54 is required. (2) "Colloidal copper oxide" is a finely ground copper oxide which comes as a thin paste. Although the copper content is stated to be but 50 percent, three-fourths of a pint of this material gave results

FIGURE 8.—Different types of spray outfits that have been found satisfactory for use in spraying tobacco-plant beds. From left to right (1) a wheelbarrow outfit, (2) a bucket pump, and (3) a barrel outfit. The cost of these ranged from $10 to $25.

about equal to 1 pound of regular red copper oxide. Some difficulty has been encountered in using this product because of the tendency of the copper oxide to settle out. It should be stirred very thoroughly before being measured. (3) "Metrox" is an 87- to 88-percent copper cuprous oxide that is a dark-red instead of a bright-red color. This material was used at the same rate as the regular red oxide but with rather poor results in one series of experiments. It did not make a good suspension. Later, a newer Metrox cuprous oxide, said to be more finely divided than that used previously, was used successfully in a subsequent series of experiments.

In addition to the copper (cuprous) oxide, other forms of copper have been tried out extensively, but so far all have proved inferior (fig. 9).

Both raw and refined cottonseed oil have been found to be entirely satisfactory. The former sometimes emulsifies a little more readily, but no differences have been found in the effectiveness of disease control. In addition to cottonseed oil, limited seedbed tests indicate that soybean oil and possibly peanut oil may be used. Mineral oil should never be used for this purpose.

The cottonseed oil must be emulsified before it can be used, and it is important to employ a suitable emulsifier. Tests have shown that the majority of emulsifiers produce mixtures that (1) are unstable in the presence of the copper, (2) spread poorly, or (3) injure tender leaves. The most satisfactory emulsifying materials tested are Lethane Spreader and Orvus or Dreft.[2]

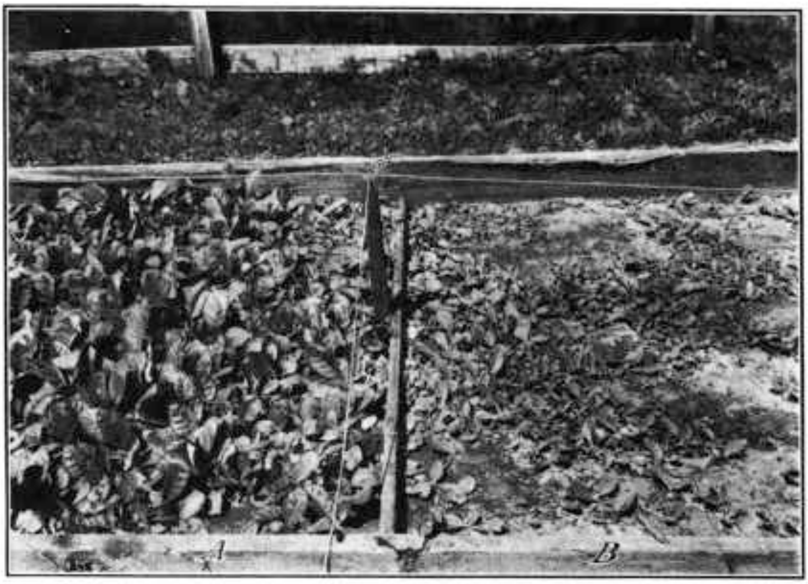

FIGURE 9.—Comparison of effective and ineffective sprays: Plot *A* was sprayed with the recommended copper oxide–cottonseed oil and plot *B* with an ammoniacal copper preparation that has been widely sold as a blue mold remedy. The plants in plot *B* suffered as severe injury from the disease as the unsprayed checks.

The emulsifier most generally used was Lethane Spreader. This at the rate recommended below gave satisfactory emulsions under a wide variety of conditions. Orvus, 1 to 1½ pints, or Dreft, 14 to 21 ounces, per gallon of oil will produce satisfactory emulsions, except where the water is distinctly hard, and, on the basis of 1938 prices, the cost of the mixed spray may be reduced when they are used. On farms where the well water is very hard, it is usually possible to obtain relatively soft water in nearby ponds or streams.

A discussion of materials should not be concluded without mention of possible concentrates that contain both the copper and the emulsi-

[2] Orvus and Dreft are reported to have as the active ingredient sodium alkyl sulphate. The former is a paste that liquefies readily with slight warming, and the latter is a solid. They are products put out by the Procter & Gamble Co., Cincinnati, Ohio.

fied oil and require only dilution with water. Such concentrates have been prepared, and two of the types that appeared most promising were tested. They did not give as good control of blue mold as the regular spray.

Mixing the spray.—Although many growers will use sprayers having a bucket or small tank that holds only 3 to 10 gallons, they will usually find it convenient to mix larger lots of 25 to 50 gallons in a separate barrel, rather than to mix numerous smaller lots. The total amount of spray that will be required, of course, can be easily and closely estimated. The following mixing directions are given on a 50-gallon basis:

Material	Quantity
Copper oxide	One-half pound of the regular red oxide or a corresponding amount of one of the other forms mentioned previously.
Cottonseed oil	One-half gallon of either raw or refined cottonseed oil.
Emulsifier	1 quart of Lethane Spreader or the proper amount of one of the other emulsifiers.
Water	To bring the volume to 50 gallons.

It is important to follow a definite procedure in preparing the spray. Do not dump all the materials in together. (1) Weigh out or measure the proper amount of each material. (2) Take a small portion of the emulsifier (about one-tenth) and add this, plus a little water, to the copper oxide. The purpose of this is to make the copper powder mix readily with water. If Cuprocide 54 or "Colloidal copper oxide" is used, this step is unnecessary. Work the copper oxide into a thin paste with a little water and set it aside. (3) Now pour the oil into the remainder of the emulsifier, having first added water enough to the emulsifier to bring the final volume of the mixture to about three times the original volume of oil. Thus for one-half gallon of oil, use 1 quart of Lethane Spreader and three-fourths of a gallon of water to give a final volume of about 1½ gallons. Emulsify this mixture by pumping it through a spray nozzle. A small, inexpensive bucket pump is very convenient; when this is used, the mixture is merely pumped from one bucket into another. However, if the sprayer has an intake so located that it will easily reach 1½ gallons of liquid, emulsification can readily be carried out in the sprayer. Use a short length of hose with a nozzle attached and pump the mixture back into itself until it remains creamy with no evidence of free oil and no droplets of free oil separate out when diluted with water. With the copper oxide worked into a thin paste and the oil emulsified, all that remains is to dilute the oil emulsion in the barrel with about 40 gallons of water; stir the copper oxide into a full bucket of water and add this to the diluted oil. Then work up any lumps of copper oxide that remain in the bottom of the bucket and add water to bring the volume to 50 gallons. The mixed spray should not be kept overnight and should always be stirred up thoroughly before using since the copper oxide settles out rather easily.

How to spray.—With proper equipment and correctly mixed spray, the next questions are how to apply it and how much to apply. The spray should be applied with good pressure, 100 pounds or more, so that it will come out from the nozzle as a fine mist that will drive in

among the leaves with some force. When plants are large, it is desirable to turn the nozzle, or nozzles, from side to side by slightly twisting the spray rod and, in this manner, hit the leaves from different angles. Some regular system should be followed in covering the beds. The amount of spray to be applied should be figured in advance on the basis of bed yardage; every grower knows the size of his seedbed. Small plants, the size of a dime, can be sprayed through the cotton cover, provided this is raised off the ground 6 inches or more; 3 to 4 gallons will spray 100 square yards. If the covers are removed, the amount of spray required will be reduced one-third. Spraying through the cover is satisfactory as long as the leaves remain flat on the ground, but as the plants begin to grow in height, it will be necessary to remove the covers for a few applications. In a very few weeks, of course, the cotton covers will be removed permanently. As the plants grow larger, more spray is required to coat the leaves, until finally toward the end of the plant-bed period, 6 to 8 gallons should be applied per 100 square yards of bed. It is important not to apply excessive amounts of spray to very young plants, as they are readily injured. Should severe spray injury occur, it may be advisable to reduce the amount of spray applied for one or two applications. After the plants begin to grow rapidly, however, they can be sprayed heavily without fear. A slight curling of the leaves of young plants and a slight flecking of the older leaves are desirable signs, since they indicate thorough spraying and do the plants no harm. Emphasis has been placed on the need for increasing the amount of spray as soon as the plants begin to grow rapidly, because in the past many growers have overlooked the necessity for doing this.

When to spray.—Spraying is a preventive treatment, and three or four applications must be made before mold becomes active, or satisfactory results will not be secured. Growers should start spraying as soon as mold is reported in the belt. They should not delay until the disease appears in their own beds. On the other hand, even when localized infection is observed about the time spraying is begun, the disease frequently makes little further development for several weeks, and this affords time for the needed three to four applications in advance of the general outbreak. It is well to remember that while an early start may slightly increase the number of applications, the cost of these is small, and a late start may result in complete failure and heavy plant damage.

Applications should be made twice a week. It is advisable to plan to spray on Mondays and Thursdays, so that if there is a delay of a day, the schedule will still not run into the week end. Some growers have missed applications at critical periods because of wet weather. This is unnecessary. The writers have sprayed several hundred beds in many localities during the past 4 years and have never found it impossible to spray twice a week. Growers often overlook the fact that after three or four applications the oil-sprayed leaves dry very quickly. Thus, plots side by side have been observed in which the sprayed leaves were completely dry at 9 a. m., while the unsprayed leaves were still wet at noon. Spraying should not be attempted when the leaves are wet, but in view of the quick drying of the leaves in sprayed beds and the fact that the spray

will be dry on the leaves half an hour after it is applied, it is easily possible to spray twice weekly regardless of weather conditions. However, if rain should fall before the spray is dry, the application should be repeated as soon as possible. Severe drought also occasionally raises the question as to whether the plants should be sprayed. In extreme cases, a spray should be omitted. Generally, it should be applied, but if the plants have grown very little since the last treatment, the amount applied should be reduced. Repeated observation has shown that sprayed plants do not wilt as severely during dry weather as the unsprayed ones. The reason it is advisable to reduce the amount, rather than omit the applications entirely, is that mold can develop freely during dry weather, particularly with the aid of fogs.

Cost of spraying.—Good bucket pumps properly equipped cost about $10; upright barrel outfits, $25. Generally these are the types of outfits found most practical.

The number of applications made, and, hence, the amount of materials used, will depend on the season and locality. The number of applications may vary from 6 to 15, but 8 to 10 is the average figure, and on this basis the cost of materials would be about $1.50 per 100 square yards of bed area. In 1938 a complete account of cost of spraying was kept for plant beds totaling 4,150 square yards on four farms in Granville County, N. C. Equipment was purchased new, and a man and car were employed by the day to do the work. The total cost for equipment, labor, and materials was $3.85 per 100 square yards of bed. If the expenditure for spray equipment were prorated over a reasonable period, the cost per 100 square yards of bed would be reduced to $2.36.

Spray injury.—A certain amount of cupping of leaves, plus a slight flecking and bronzing, is a common occurrence on young plants. This is of no consequence unless it is excessive. Serious injury can be caused by the use of more copper oxide or oil than is recommended, by applying excessive amounts of spray to young plants, and by failure to emulsify properly the oil or make a good water suspension of the copper oxide.

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